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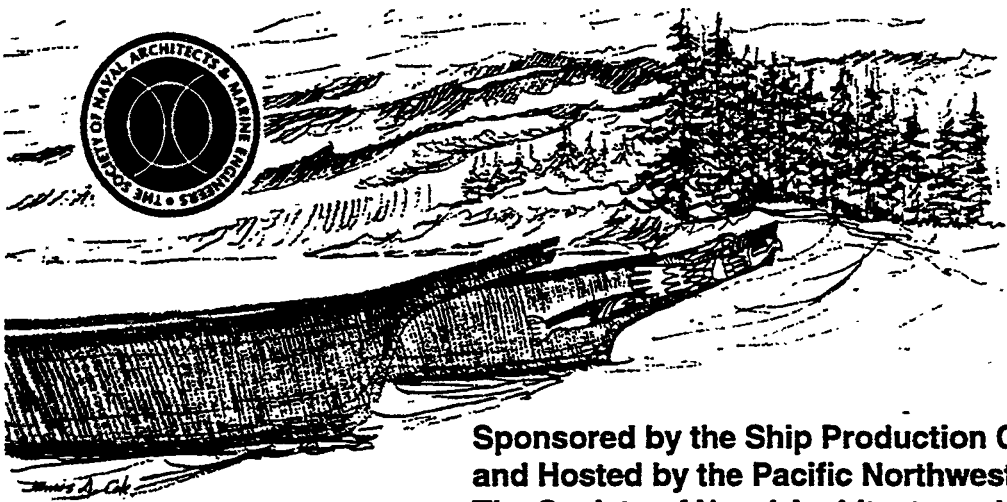

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Standard Outfit Package Units in the LPD 17 Ship Design: A Production Impact Study

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ABSTRACT

Standard outfit package units for reverse osmosis plants, fire pumps, steering gear, and sanitary spaces were proposed for the LPD 17 amphibious transport dock ship design. The ship was in the preliminary design stage, and it was necessary to determine how this shift to outfit modularity would affect the ship procurement program. Because the use of package units would not have a significant impact on the overall characteristics and performance of the ship, the focus of the investigation was on material ordering and production scheduling. The analysis took account of zone-area-stage outfitting methods and also more traditional practices. With either approach, it was found that the package units did not present any schedule or procurement problems. This particular study was focused on a very specific issue, but the approach is applicable to a wide range of production impact assessment problems.

INTRODUCTION

A new series of standard shipbuilding outfit package units for naval construction is being developed by the Navy's Affordability Through Commonality Program (ATC). These package units are also variously known as common modules, standard outfit modules, or other similar names; the nomenclature has not yet been standardized. This production impact study was undertaken in order to help integrate four types of package units into the design of the LPD 17 class amphibious ship. The four units studied were ATC's reverse osmosis, sanitary space, fire pump, and steering gear outfit package unit designs.

The goal of this study was to identify production process implications of using the four ATC package units in the LPD 17 design, and in particular to determine construction schedule impacts. This was accomplished by integrating the modules into a notional construction strategy that was under development for the LPD 17. The general outline of the analysis was as follows.

a) The LSD 49, whose principal characteristics are compared to those of the LPD 17 in Table I, was identified as the most similar ship which had already been built. The analysis started with an existing ship because the notional LPD 17 construction strategy was not detailed enough and did not include a compartment

Characteristic	LSD 49	LPD 17
General		
Length (overall)	186 m (610 ft)	208 m (684 ft)
Beam (extreme)	25.6 m (84 ft)	31.9 m (105 ft)
Draft	6.1 m (20 ft)	7 m (23 ft)
Displacement (full load)	approx. 17,000 long tons	approx. 24,000 long tons
Total accommodations	approx. 400 crew approx. 400 troops	approx. 495 crew approx. 750 troops
Propulsion		
Main engines	4 medium speed diesels	4 medium speed diesels
Number of shafts	2	2
Shaft horsepower	33,000	40,800
Operations		
Operational mission	Transport and launch loaded amphibious craft and vehicles with crews and embarked personnel in an amphibious assault. Render limited docking and repair service to small ships and craft. Act as primary control ship in an amphibious assault.	Amphibious transport dock ship for Marine landing forces via helicopters, and amphibious assault vehicles
Flight deck capabilit	Two helo landing spots	Four helo landing spots
Hangar bay	None	Yes
Well deck capability	LCAC and conventional craft	LCAC and conventional craft

Table I Selected characteristics of LSD 49 and LPD 17.

closeout schedule or a block erection schedule.

b) The time frame or insertion point for fitting each ATC module into the LSD 49 baseline schedule was determined.

c) The findings were extrapolated to the LPD 17.

d) The material ordering lead times for the modules were derived.

e) The material ordering lead time was checked against the baseline schedule to ascertain whether or not a potential conflict existed.

In conducting this study, the LPD 17 construction planning information used (block breaks, scheduling information, and related information) was taken from preliminary elements of a notional build strategy which was under development by the LPD 17 design team. The notional build strategy was intended to help the ship design team to incorporate producibility considerations into the design of the ship.

PRODUCTION IMPACT STUDIES: CONCEPTS AND METHODS

During the planning of a new ship acquisition program, feasibility studies are performed to determine how various design constraints will affect ship acquisition. A baseline ship design is developed, a change is specified, and the design is modified to accommodate the change. A comparison of the modified ship design to the baseline reveals the impact of the change. Ship impacts may be broken down into impacts on principal dimensions, weight, stability, cost, combat capability, mobility, damage resistance, and so on. The results are used in evaluating proposed future ship configurations and systems, and, at a higher level, in developing ship operational requirements and in planning and prioritizing research and development projects (Sims, 1993).

Ship impact studies are an essential tool, but for certain kinds of design decisions they do not reveal all of the significant consequences. A ship impact study looks at a ship only as a finished product. However, some design changes are intended to affect the acquisition process more than the final ship. In these cases, an appropriate type of process impact study must be carried out.

Incorporating the four ATC common modules into the LPD 17 design is expected to have relatively little final ship impact (*Modularity*, 1993). Instead, the modules are intended to benefit the program by reducing shipbuilding cost and time. In other words, the completed ship will not change significantly, but there will be improvements in the way the ship is built. This production impact study was conducted to study different design options whose major impacts will be on production processes rather than the final product.

The value of doing production impact studies at increasingly earlier stages of design is becoming clear, and some progress has been made in developing techniques and criteria for evaluating the construction cost differentials of ship design options (Wilkins, Kraine, and Thompson, 1993). This study of the LPD 17 program looked at the impacts of the proposed design change (incorporation of ATC package units) on production scheduling and material ordering. Because the LPD 17 was in the preliminary design stage, construction planning had not yet been done to a level of detail which permitted production impacts to be investigated. The LSD 49 was chosen as the baseline for this project because it was the most similar existing ship; then, the methods and findings were transferred to the LPD 17.

The basic idea behind this analysis was to find construction blocks which contained a function that could be served by an ATC module, replace the existing equipment with the module, and find the point in the ship construction schedule where the module could be fitted. This date -- when the module is attached to the next higher assembly -- is called the insertion point. Subtracting the module's material ordering lead time gives the date when the shipyard must award the purchase order to the manufacturer, or alternatively, when the yard must begin to build it at its own facility. The ATC module insertion point and purchase order award date are studied in reference to the ship construction plan to determine whether incorporating the modules will cause any disruptions in the production process or schedule.

This procedure may be summarized in eight steps.

a) Identify compartment locations on the LSD 49 where ATC common modules could replace existing systems.

b Associate each such compartment with a construction block.

c) Lay out the construction schedule for each block containing a module, from start of fabrication to erection.

d) Select the start of on-block outfitting as the module insertion point.

e) Identify LPD 17 compartment locations for the ATC modules, and associate each such compartment with a construction-block.

f) Estimate construction schedules for the LPD 17 blocks using the LSD 49 schedules, step (c), as a guide. For each LPD 17 block, identify the start of on-block outfitting, and use this as the ATC module insertion point (similar to LSD 49, step (d) above).

g) Estimate module ordering lead times.

h) Obtain the purchase order award date by subtracting the estimated material ordering lead time from the module insertion point.

The delivery date, step (d), is the earliest and therefore most demanding from the standpoint of production planning. Actual dates will vary with differences in facilities, production processes, labor, order book, and other operational factors. The earliest delivery is required in cases involving large pre-outfitted blocks built away from the erection site. This process depends on delivery of modules during the on-block outfitting stage. Shipyards which do less extensive block pre-outfitting are able to take delivery of the modules at a later stage of construction.

ATC STANDARD OUTFIT PACKAGE UNITS

The sanitary space module design is a pre-outfitted, box-like, non-structural enclosure equipped with toilets, urinals, sinks, showers, a service sink enclosed in its own mop and broom locker, peripheral amenities, compartment lighting and power, heating, ventilating and air conditioning services, and associated piping. It may be open at the top, bottom, or at both (*Modularity*, 1993). The design of this module is subject to change in virtually all respects including geometry and capacity. However, the material ordering lead time and insertion point will not change significantly as these design issues are resolved.

The fire pump module is built around the Navy standard 3,785 liters/min. (1,000 gal./min.) fire pump, which is designed to provide pressurized sea water for fire fighting, sanitary uses, wash down, and primary or back-up cooling service. The pump-motor assembly is resiliently mounted to a sub-base. Bolted to this sub-base is a frame assembly that supports the pump ancillaries including a motor controller, automatic bus transfer, gage board and casualty power terminal. The pump inlet and outlet will be fitted with flexible connections by the shipbuilder because their length and arrangement are best left to the detail design of ship's piping and machinery arrangement. The weight is approximately 1,700 kg (3,800 lb.) The sub-base is approximately 180 mm (7 in.) deep and the scantlings have been selected to support the equipment weight using naval surface combatant shock design criteria. This module is intended for use aboard a combatant type vessel. For ships where noise and shock criteria do not apply, the resilient mounting and flexible connections could be deleted or replaced with solid mounts and pipe, but otherwise the design and production process would be identical (*Modularity*, 1993). Offering an optional mounting would not introduce enough variety to significantly impair the commonality of the module. In fact, the provision of application-specific mounts or foundations can in some cases advance commonality by allowing standard outfit package units to be installed in a wider range of operational environments than they would otherwise be able to serve. In these cases, effective module designs must strike a balance. The number and scope of options must not be so great as to impair commonality, but on the other hand options that greatly increase the potential applicability of the module should be evaluated for possible incorporation.

The reverse osmosis module is a 45,420 liter/day (12,000 gal./day) unit which processes sea water into fresh water. The ATC module is made up of a pump sub-module, a reverse osmosis sub-module and a filter sub-module which are resiliently mounted for structure borne noise reduction. The module also incorporates a motor controller and gage panel, which are hard mounted. The interconnecting piping incorporates the necessary instrumentation and control devices and is flexibly connected to the pump and reverse osmosis sub-modules. The piping is resiliently supported from the module sub-base. The estimated wet weight of the module is approximately 6,800 kg (15,000 lb.) The sub-base is approximately 23 cm (9 in.) deep and the scantlings are sized to support the equipment weight using naval surface combatant shock design criteria. Structure-borne noise control features are consistent with DDG 51 Class criteria (*Modularity*, 1993).

The steering gear module is made up of sub-modules including rudder actuator assemblies, hydraulic power units, a hydraulic fluid power supply system, a hydraulic fluid storage system, and an emergency fill/drain pumping system. Some recent U.S. Navy ship designs (DD 963, FFG 7, CG 47, and DDG 51 classes) already show commonality in the power units, service tank units, storage tank units, and fill/drain/emergency pumps (hand and motor driven). The rams and cylinders and type of steering gear are diverse, being determined by rudder stock position, tiller flat space and torque requirements at a 30 degree rudder position. All power units are presently in a modular form. The motors, pumps, trick wheel/differential controllers, filters, valves, and servo control valves are mounted on a skid (*Modularity*, 1993).

SHIP CONSTRUCTION PROCESSES AND ATC PACKAGE UNITS

The overall processes of ship construction are considered in finding the right schedule point for the insertion of the ATC modules. Ship construction work may be classified in several ways depending on what aspect of the work is of interest. Under the product work breakdown structure concept, shipbuilding work activities are grouped into three primary types: hull construction, outfitting, and painting. Hull construction and outfitting are further broken down into fabrication and assembly, which are sequential stages of production.

The notional construction strategy for the LPD 17 uses the hull block construction method and zone outfitting. Zones are geographic parts of the ship. The boundaries are laid out in the construction plan and cover functional parts of the ship; for example hull, machinery, and superstructure. For warships, zones may be added for combat systems (Storch, Hammon, and Bunch, 1988, p. 62). Within a zone, work is organized by problem area (production process attribute) and by production stage, thus giving the complete zone-area-stage product oriented work breakdown system.

For outfitting work, the object is to plan the work to take advantage of the optimal environment for the particular production process involved. There are three stages for outfit work: on-unit, on-block, and on-board. High outfitting productivity is most readily achieved when the work is performed at the earliest possible of these three stages (Chirillo, 1983). For this reason, and because it represents the most difficult constraint on planning, the earliest feasible stage was chosen for the insertion of each ATC module into the ship production schedule.

On-unit Outfitting

The assembly of components into package units constitutes on-unit outfitting and this is the earliest outfitting stage (Storch, Hammon, and Bunch, 1988, p. 81). The best place for this activity is an indoor shop. Shop work provides a controlled climate with good lighting, access to tools, and the opportunity to work down hand. Work may be grouped according to the type of production machinery and processes required. The ATC modules are examples of interim products designed for on-unit assembly. They are expected to be treated as purchased material, or to be built at a (preferably indoor) manufacturing facility at the shipyard. After being assembled on-unit, the ATC modules may be used as components for the assembly of larger package units, or they may be designated as final outfit units and then installed on-block. For this study, the ATC package units were scheduled to be assembled on-unit and subsequently installed (inserted) on-block.

On-block Outfitting

Outfitting on-block is the assembly of outfit components on a structural subassembly or block, prior to its erection (Storch, Hammon, and Bunch, 1988, p. 81).

On-board Outfitting

Outfitting on-board includes, and theoretically would be limited to, the connection of units and/or outfitted blocks, final painting, and tests and trials. In practice, however, this stage includes some installation of outfit components, in a hull at a building position or outfitting pier, which are not incorporated on-unit or on-block.

SCHEDULE INSERTION POINTS

There may be several opportunities for inserting ATC package units into the ship construction schedule. The designs of the four modules are subject to change, but they are likely to remain suitable for on-unit assembly followed by installation (insertion into the ship construction schedule) during the on-block stage of construction. For this study they have been scheduled for insertion into the blocks at the start of the on-block outfitting stage in the block erection schedule. Assuming that the ATC modules are final units and that they are not used as subassemblies for further on-unit outfitting, this is a conservative approach because the beginning of on-block outfitting is the earliest possible point that final package units might be required in order for other work to proceed. When the design becomes more firmly fixed, the degree of precision in planning and scheduling by the shipyard can increase. At that time, a later insertion point may be chosen for reasons such as the need for the block to be in an upright position, a requirement to land large, heavy equipment by overhead crane, late delivery of material, or a need to install a module after blasting and painting.

ORDERING LEAD TIMES

Modules and vendor supplied components should be ordered for just-in-time delivery, with a prudent amount of positive slack time to allow for contingencies, especially for items on the critical path. Unnecessarily early ordering is wasteful because carrying costs are increased and module or component purchasing expenses are incurred earlier, and late delivery is costly because it causes rework in planning and production. Timely material identification, ordering and receipt is therefore a prerequisite for efficient ship construction.

Order scheduling depends on accurate lead time estimates. Ordering lead time for modules is the time between award of the purchase order and the ATC module insertion point. This study does not include an analysis of shipyard actions prior to purchase order award. There are five types of activities to consider.

a) Manufacturer's planning: design, technical data approval, and other planning functions.

b) Material lead time from subcontractors: material and parts procurement, especially for components on the critical path.

c) Manufacturing, testing, and preparation for shipment.

d) Shipping time.

e) Shipyard receiving, inspection, and preparation.

The overall duration of the five activities is the ATC module ordering lead time. Subtracting this from the module insertion point gives the date that the module purchase order should be awarded to the vendor. This date does not include consideration for additional lead time that may be needed if the order is large enough to exceed the capacity of the manufacturer(s). In addition to material ordering lead time, some additional time before the order point will be required by the shipyard for acquisition planning activities. Shipyard actions which take place before the material order point are not analyzed in this study.

The information used in the module ordering lead time estimates came from the Navy's annual survey of the shipbuilding industrial base (*Manufacturing Lead Times*, 1993). This study is a planning guide based on peacetime conditions and does not include wartime or mobilization considerations.

LSD 49 ANALYSIS

Examining the LSD 49 was the first step in determining the production impact of the ATC standard outfit package units.

Locate Compartments Where ATC Modules Could Replace Existing Systems

Compartment completion schedules and general arrangement drawings were studied for the functions of each compartment. All compartments where planned ATC modules could fit were tagged for analysis. As an example, the LSD 49 general arrangement drawings show a sanitary space in compartment 02-56-4-L, in the superstructure. This sanitary space will be traced through the production impact analysis process.

Associate Compartments With Blocks

Each identified compartment was associated with a construction block using the LSD 49 compartment completion schedule. The compartment completion schedule assigns compartment 02-56-4-L to block 430. Production planners at Avondale Industries, Inc. selected block breaks to suit their construction strategy for the LSD 49. Different block breaks could be used depending on the availability of facilities, material, or manning at the time of construction of a particular hull.

Derive Construction Schedules

The block construction schedule, ship erection schedule, and other documents were used to derive a construction schedule for each block containing an ATC module, from start of fabrication to erection. Not all schedules were referenced to the same milestone, so all were normalized to start of construction of the ship. Start of construction is a major milestone, and is usually defined in naval shipbuilding contracts to occur when the first structural pieces are cut. The start of construction was estimated at six months before keel laying; this was the approximate average of the LSD 49 class ships built by Avondale.

The block erection and outfitting schedule showed the following sequence for block 430.

a) Pre-fabrication begins 5 months after start of construction.

b) Fabrication begins 6 months after start of construction.

c) On-block outfitting begins 8 months after start of construction.

d) Final assembly begins 10 months after start of construction.

e) Erection begins 15 months after start of construction.

This information is plotted in Table II as the "Duration of block construction" bar for Item No. 3.

Identify Start of On-Block Outfitting as Module Insertion Point

The first scheduled on-block outfitting point of each applicable compartment of the LSD 49 was selected. These module insertion points are shown by a letter "I" in the block construction bars in Table II. On-block outfitting of block 430 began eight months after start of construction, and this point is marked on Table II with an "I" at Item No. 3.

	Baseline Milestone =>	SC*																						
	Months After																							
	Start of Construction ==>	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Block Numbers																								
	SANITARY SPACE COMMON MODULES																							
2241	(Assumed to be first)												I											
2293	(Assumed to be last)																I							
	FIRE PUMP COMMON MODULES																							
2121, 2122																		I						
3423, 3424															I									
3123, 3124											I													
3323, 3324														I										
3023, 3024													I											
	REVERSE OSMOSIS COMMON MODULES																							
3323																I								
3023																I								
	STEERING GEAR COMMON MODULES																							
4321, 4322													I											

Legend:

[dotted box] = Duration of block construction from start of (structural) fabrication until erection. .

"I" = Earliest insertion point of module within this block.

*SC = Start (structural) construction (of ship).

Table III Insertion points for ATC common modules in LPD 17 notional build strategy.

EXTRAPOLATION TO THE LPD 17

The next phase took the LSD 49 block construction durations and module insertion points, and applied them to the LPD 17 plans.

Identify LPD 17 Compartment Locations

LPD 17 compartment locations for the common modules were identified, and each such compartment was associated with a construction-block. The preliminary general arrangement drawings were used. The locations for fire pump, reverse osmosis and steering gear common modules were proposed by the ATC Program (*Modularity*, 1993). Sanitary space common module locations were not yet fixed, so the two potentially applicable compartments that were the earliest and latest in the notional block erection schedule were selected for analysis in order to bracket the problem. These were blocks 2241 and 2293.

Estimate Construction Schedules

Construction schedules for the LPD 17 blocks were estimated using the LSD 49 block construction schedules as a guide. For each LPD 17 block, the start of on-block outfitting was identified, and this was used as the ATC module insertion point, as was done for the LSD 49 analysis. The major milestones and construction schedule of the LPD 17 were taken to be the same, or slightly longer than, the LSD 49. This is a conservative estimate. The notional LPD 17 erection schedule (*LPD 17 Hull Erection Study*, 1993) showed the block erection points. The blocks were then assigned the same, or a slightly longer, construction schedule as the corresponding block from the LSD 49. Longer schedules were used when the LPD 17 compartment or block configuration was more complex. Within these block construction schedules, the insertion points for the ATC modules were located at either the same point as for the LSD 49, or at a pro-rated point if the LPD 17 block construction schedule was estimated to be longer.

Block 2241 was scheduled to begin fabrication approximately six months after start of construction, and erection was estimated at fifteen months after start of construction. The start of on-block outfitting and therefore the insertion point of the sanitary module into this block was then estimated at eleven months after start of construction. These points are shown in Table III.

Estimate LPD 17 Lead Times

The sanitary space module design was examined and potential long lead components were identified. These are non-stock items that have to be fabricated or manufactured to order, and are listed in Table IV. For each module, two months was allowed for manufacturer's planning, and this is shown as Item 1, Table V. This is probably conservative, because the ATC modularity is intended to streamline this process. The longest lead times, five months each for the relief valve and exhaust fan, determined the duration of Item 2, material lead time from subcontractors, on Table V. Item 3, manufacture, test, and prepare for shipment was estimated at four months. Items 4 and 5, shipping time and shipyard receiving, inspection, and preparation are variable and one month was allowed for each. The same process was carried out to calculate the lead times for the other three ATC modules.

The total ordering lead time for the module is not equal to the sum of the individual sub-process lead times described above because of task overlap. For the sanitary module, there are three months of overlap so the module ordering lead time is ten months rather than thirteen, as shown in Table V.

The purchase order award date was determined by subtracting the estimated material ordering lead time from the module insertion point. The order award date is shown by an "O" in Table VI.

The insertion point for an ATC sanitary module to be placed into block 2241 of the LPD 17 notional build strategy is eleven months after start of construction (Tables III and VI). The sanitary module purchase order award date is estimated at ten months prior to that (Table V). The purchase order award date is then one month after start of construction. This is marked on Table VI with an "O". This estimate is intended to be conservative and if it is, then the actual purchase order award dates could be later. If, for example, the modules are purchased from existing stock, or if they become a commodity item and are manufactured using efficient series production processes, the delivery times could be significantly shorter and the ordering lead times reduced correspondingly.

CONCLUSIONS AND RECOMMENDATIONS

The results of this study are shown in Table V, "ATC module ordering lead times", and Table VI, "Order points for ATC common modules in LPD 17". The module ordering lead times chart is useful for ATC systems engineers. It shows that material lead time from sub-contractors is the critical item to address if module lead times are to be reduced. The module

ATC Sanitary Space Common Module	
Component	Material Lead Time
Resiliently mounted urinal	2 weeks
Resiliently mounted water closet	2 weeks
Overhead lighting	4 months
Over mirror lighting	4 months
Door, non-watertight	4 months
Bulkhead panels	3 months
Heater (hot, fresh water)	2 months
Exhaust fan	5 months
Reducing valve (flushing water)	4 months
Relief valve (flushing water)	5 months
Steel plate for deck	2 months

ATC Fire Pump Common Module	
Component	Material Lead Time
1,000 gpm titanium (prop) fire pump	10 months
Motor 150 HP	11 months
Motor controller 440 AC 1 speed	7 months
Automatic Bus Transfer (ABT)	6 months
Gage board	1 month
Casualty power terminal	1 month

ATC Reverse Osmosis Common Module	
Component	Material Lead Time
Reverse osmosis unit	13 months

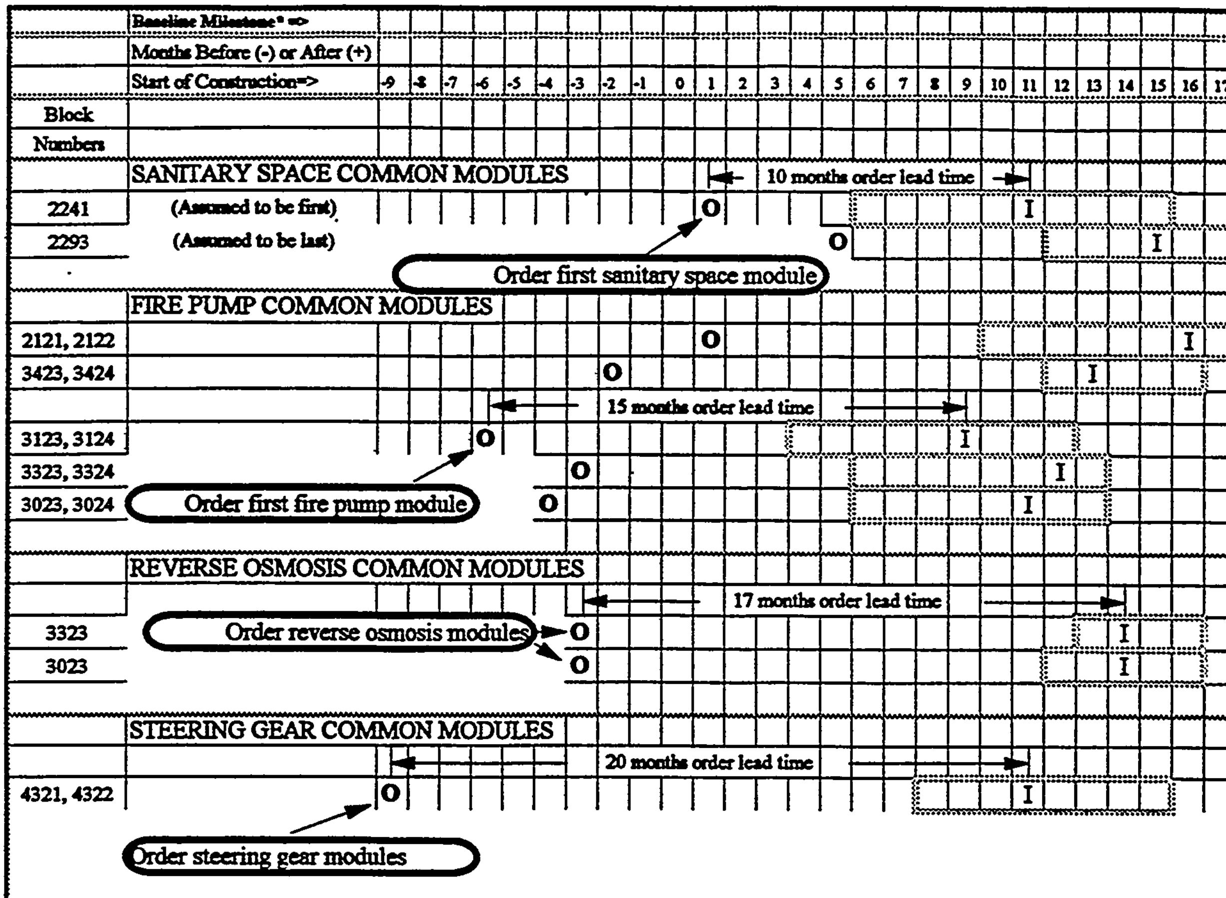
ATC Steering Gear Common Module	
Component	Material Lead Time
Steering gear assembly*	14 months

*Includes pump, motor, hydraulic fluid stowage tank, ram, tiller, and angle indicator.

Table IV Material lead times from sub-contractors for selected components.

	Activity	Months After Award of Purchase Order (1–20)
	Sanitary Space Common Module	
		Exhaust fan & relief valve have 5 months MLT
1	Manufacturer's planning	
2	Material lead time from sub-contractors	
3	Manufacture, test and prepare for shipment	
4	Shipping time	
5	Shipyard receiving inspection and preparation	
	Total duration	10 months order lead time
	Fire Pump Common Module	
		150 HP motor has 11 months MLT
1	Manufacturer's planning	
2	Material lead time from sub-contractors	
3	Manufacture, test and prepare for shipment	
4	Shipping time	
5	Shipyard receiving inspection and preparation	
	Total duration	15 months order lead time
	Reverse Osmosis Common Module	
		Reverse osmosis unit has 13 months MLT
1	Manufacturer's planning	
2	Material lead time from sub-contractors	
3	Manufacture, test and prepare for shipment	
4	Shipping time	
5	Shipyard receiving inspection and preparation	
	Total duration	17 months order lead time
	Steering Gear Common Module	
		Steering gear assembly has 14 months MLT
1	Manufacturer's planning	
2	Material lead time from sub-contractors	
3	Manufacture, test and prepare for shipment	
4	Shipping time	
5	Shipyard receiving inspection and preparation	
	Total duration	20 months order lead time

Table V ATC common module ordering lead times.



Note: Award of contract to start construction assumed to be approximately 2 years for the lead ship.

Legend: [dotted box] = duration of block construction from start of (structural) fabrication until erection.

"O" = Order award point for ATC common modules

"I" = Earliest insertion point of module within this block.

*SC = Start (structural) construction (of ship).

Table VI Order points for ATC common modules in LPD 17 notional build strategy.

With the greatest standard commmercial parts content the sanitary space module, is the module with the Shortest lead time.

The order point chart, Table~shows that the earliest order award point for any of the four ATC Standard outfit modules occur's nine months before start of construction. If three months are allowed for the shipyard's pm-purchase order activities such as the bid process collection of vendor furnished information another actions, then the shipyard must begin the module procurement process twelve months before the

Historically, for lead ship of a class similar in size and complexity to the LPD 17, construction has started approximately two years after award of the shipbuilding contract Twelve months prior to star tof constrution is then equivalent to twelve months after contract award, and so there is twelve months of slack time available before any module procurement action must take place. It is reasonable to conclude, then that incorporation of the ATC standard outfit unit modules will have no adverse impact on the construction of the LPD 17 class lead ship.

This one year buffer is based on historical data on the time needed to achieve construction start-up. Maintaining existing schedule norms is not the goal of the LPD 17 design for production; significant reductions are sought. The ATC module lead times in this analysis, however, werealso based on historical performance and the ATC program through its streamling of the design, planning material ordering and production tasks for its module system intends not only to support but also help drive the reductions in overall ship procurement times.

There should be few problems in the implementation of the ATC standard outfit package unit system All domestic shipyards capable of building the LPD 17 are familiar with the use of outfit package units similar in planning requirements to the four ATC modules studied so the modules introduce no unproven production technologies.

The aspects of ship procurement which have a potential impact on the results of this study are the contacting and construction processes and the capabilities of the shipbuilding industrial base. If the lag between award of a shipbuilding contract and the Start of construction is reduced to less than twelve months, then it will be necessary to make corresponding gains in the speed of module procurement. The capability of the shipbuilding industrial base becomes factor if all of the module manufacturers are overloaded by large orders, in which case the material ordering lead times could be prolonged. Furthermore, if the construction strategy differs significantly from the baseline LSD 49 process used here, then the insertion points could be earlier. Investigations of these issues could be the subject of follow-up study.

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